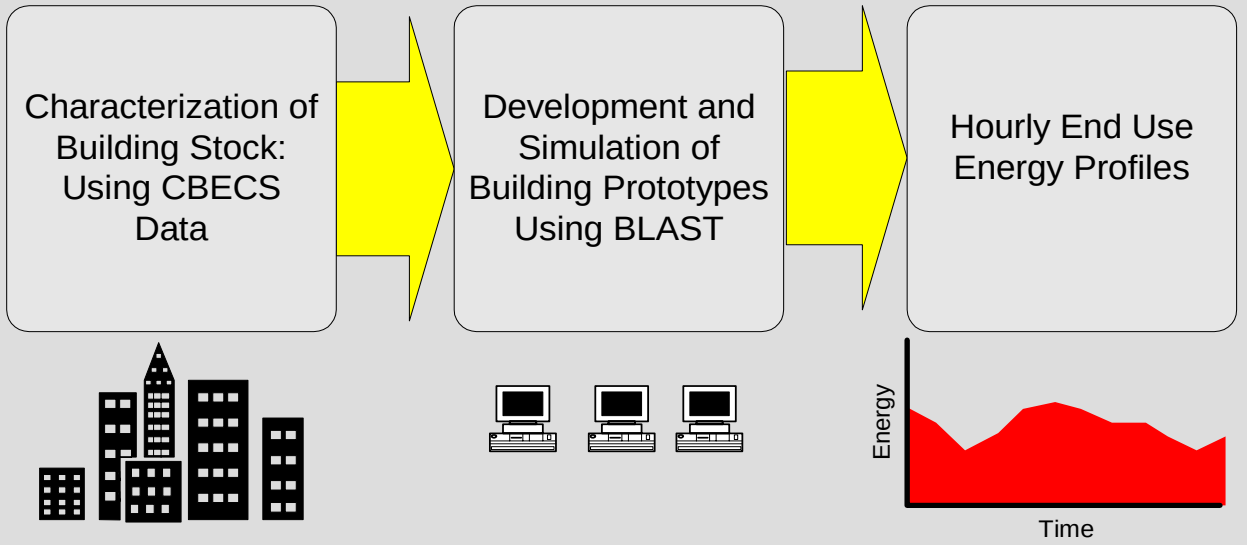
Commercial Building Energy Use and End Use Load Characterization Analysis

Unitary Air Conditioner and Heat Pump Standards Rulemaking

Overview

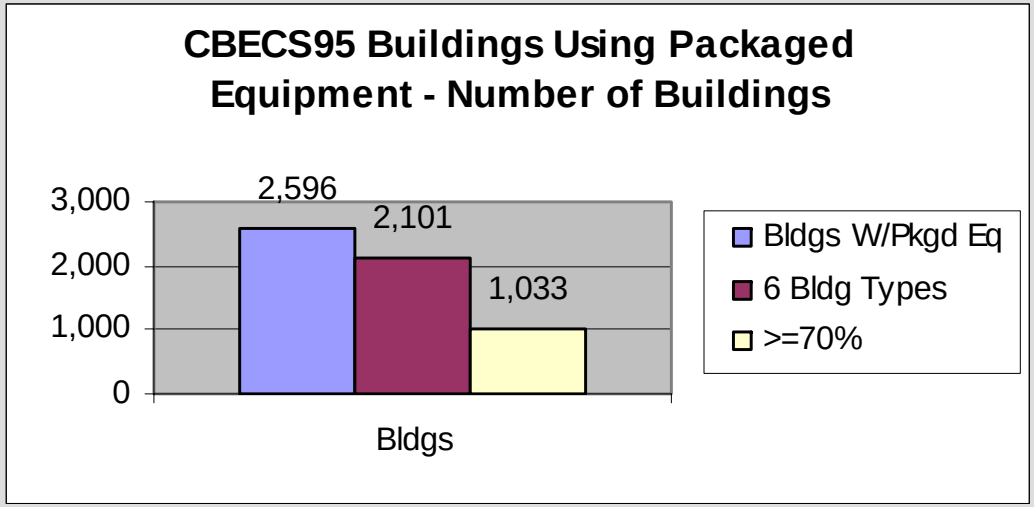
The purpose of the building energy use and load analysis is to assess the energy and peak demand savings potential of different equipment efficiencies across the range of commercial buildings and climate zones.

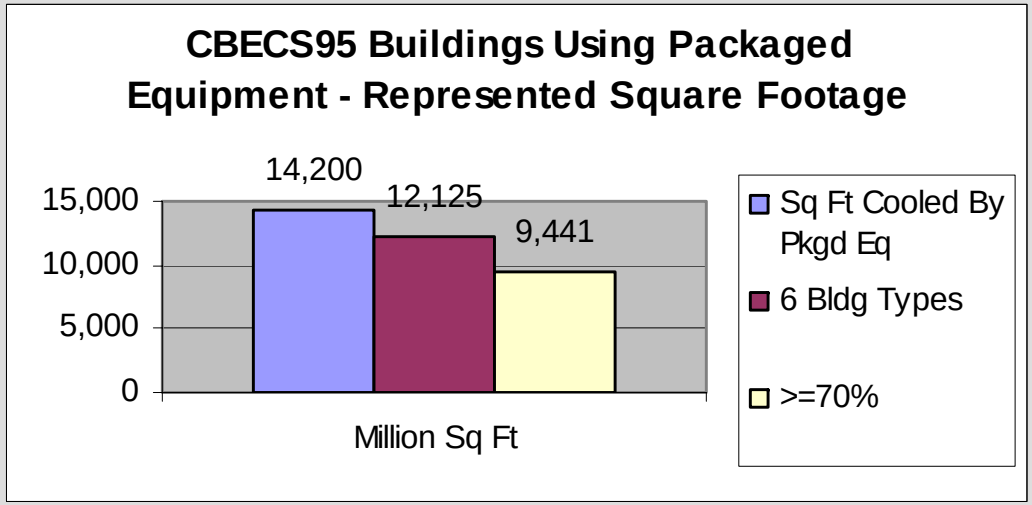
- Used a subset of the publicly available Commercial Buildings Energy Consumption Survey (CBECS), developed by the US Department of Energy (DOE) Energy Information Administration (EIA), to characterize buildings.
- Used the Building Loads Analysis and System Thermodynamics (BLAST) software, developed by the US Army, as the building energy simulation tool.



Representative Building Set

- Based on 1995 CBECS Data
- Six Building Categories
- Minimum 70% Floor Space In Each Building Cooled by Packaged Equipment
- 1033 Buildings Simulated





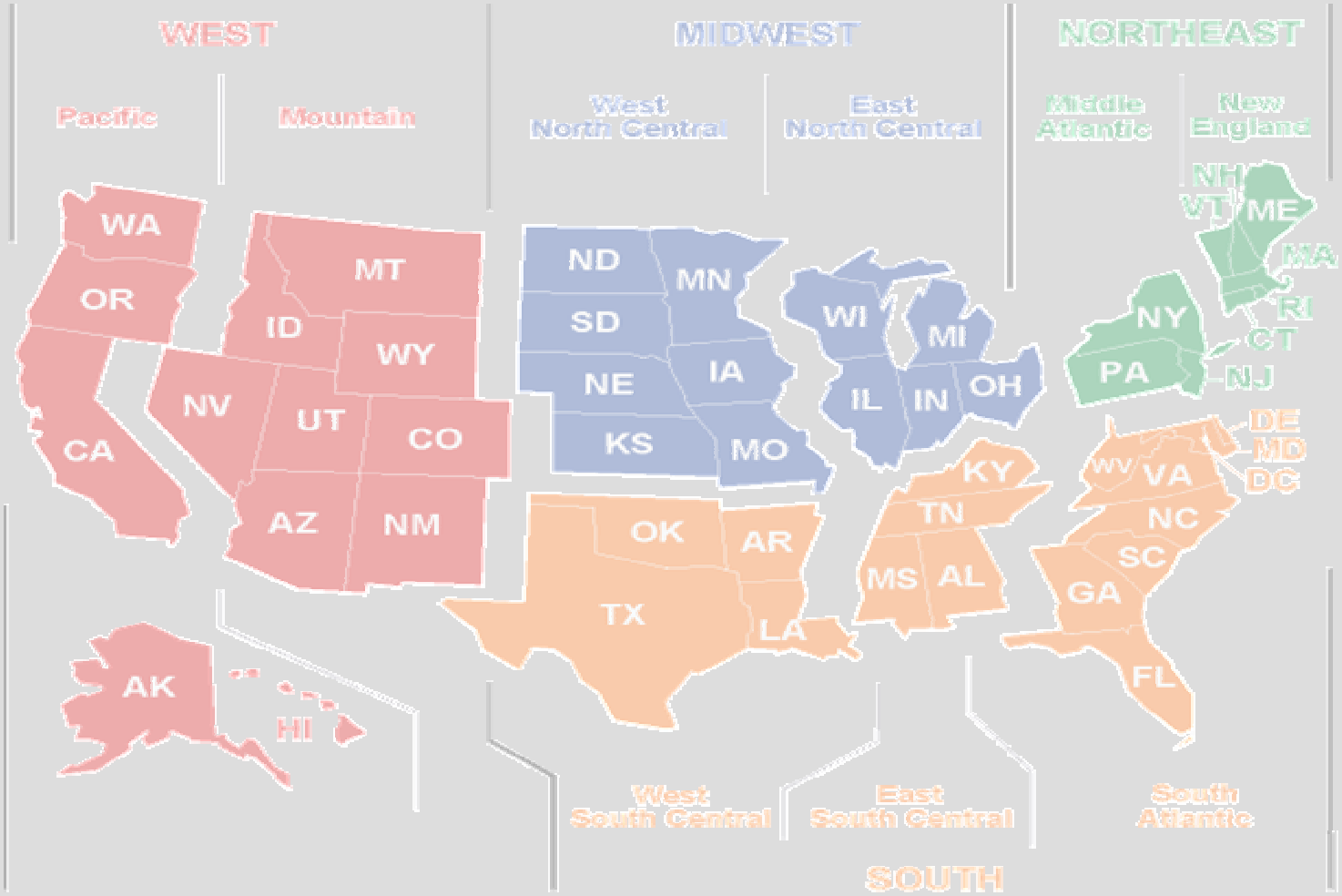
Principal Building Categories

Building Category	CBECS Principal Building Activity Included in Building Category
Assembly	Public Assembly
Education	Education
Food Service	Food Service (Restaurants)
Office	Office/Professional, Health Care (outpatient)
Retail	Mercantile/Services, Strip Shopping, Enclosed Shopping Center/Mall, Retail (except Mall), Service (except Food)
Warehouse	Warehouse (non-refrigerated)
Excluded Principal Building Activities	Laboratory, Food Sales, Public Order and Safety, Industrial/Manufacturing, Agricultural, Warehouses (refrigerated), Religious Worship, Health Care (Inpatient), Nursing Home, Lodging, Residential, Indoor Parking Garage, Other

Average Building Characteristics

Building Type	Average Floor Area (sf)	Median Year	Number of Floors	Average Weekly Hours Open
Assembly	10,861	1974	2	59
Education	14,416	1972	1	50
Food Service	5,795	1974	1	104
Office	10,799	1979	2	76
Retail	17,751	1976	1	81
Warehouse	18,311	1976	1	42

Building Distribution by Census Division



Building Distribution by Category per Census Division

CENSUS DIVISION	Assembly	Education	Food Service	Office	Retail	Warehouse	TOTAL
East North Central	16	6	10	55	55	3	145
East South Central	10	8	5	20	37	3	83
Middle Atlantic	9	8	5	36	36	4	98
Mountain	7	7	2	23	12	0	51
New England	3	2	3	23	16	3	50
Pacific	10	19	10	90	74	7	210
South Atlantic	10	18	7	62	89	11	197
West North Central	4	3	2	18	28	0	55
West South Central	6	28	13	30	61	6	144
Total	75	99	57	357	408	37	1033

Data Sources for Key Simulation Inputs

Data Source	Simulation Inputs
Direct from CBECS	Building type, floor area, number of floors, wall construction, roof type, occupancy density, economizer use, temperature setback
Inferred from CBECS	Typical Meteorological Year (TMY2) station for weather data, Window Wall Ratio (WWR), aspect ratio, schedules
Derived from Other Sources	Lighting power density, equipment power density, occupancy density, infiltration, peak ventilation, activity level, Energy Efficiency Ratio (EER)
Values for Inputs Chosen from Population Distributions	WWR, aspect ratio, system over-sizing factor

Key Simulation Inputs – Schedules

- Five schedule types
  - Monday through Friday
  - Monday through Friday and Saturday
  - Monday through Friday and Sunday
  - Open 7 days per week
  - Open 7 days per week, 24 hours per day

- Occupied hours for each schedule type based on CBECS95 reported number of days and hours open per week

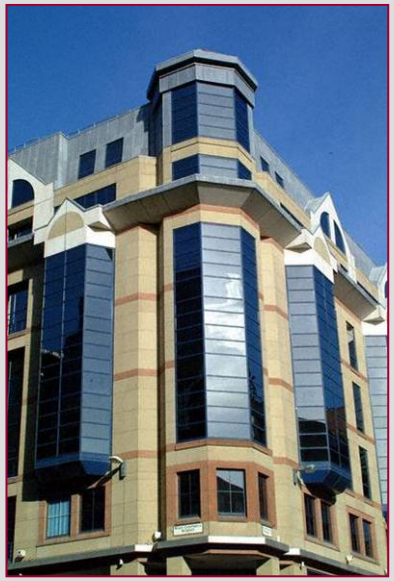
Key Simulation Inputs – Internal Loads

- Lighting – estimated peak loads based on projected power levels for 2015 (derived by Pacific Northwest National Laboratory [PNNL] and Lawrence Berkeley National Laboratory [LBNL])
- Plugs – characteristic peak loads by building type based on DOE Screening Analysis (PNNL, April 2000)
- Occupancy – office and warehouse based on CBECS, others based on DOE Screening Analysis

Key Simulation Inputs – Internal Loads

Building Type	Lighting Peak Power Density (W/ft^2)	Plug Load Peak Power Density (W/ft^2)	Occupancy Peak Density ($people/1000ft^2$)
Assembly	1.59	0.19	16.0
Education	1.45	0.48	10.7
Food Service	1.75	1.20	11.0
Office	1.32	0.64	Average = 2.96 Range: 0.042 – 31.44
Retail	1.88	0.40	2.22
Warehouse	1.19	0.15	Average = 0.44 Range: 0.089 – 3.5

Key Simulation Inputs – Building Characteristics



- Roof
  - Presence of roof insulation indicated in CBECS95
  - Used built-up (flat) roof construction (most typical)
  - Roof insulation set at R-19 for insulated roof
- Wall
  - Presence of wall insulation indicated in CBECS95
  - Used R-11 for insulated frame walls
  - Used R-6 or R-11 for insulated mass walls
- Windows
  - Presence of tinting and multi-pane windows indicated in CBECS95
    - If tinted, defined as standard gray/green tinted glass
  - Provided for the probability of low-e glass for building constructed after 1985 in all but warmest CBECS climate region
  - Assigned U-values and shading coefficients from American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Handbook of Fundamentals (2001) based on tint/no-tint, single/double pane, presence of low-e
- Aspect ratio – random assignment based on CBECS92* distribution
- WWR – random assignment based on CBECS92* WWR bins and random assignment within each CBECS92* bin (see following slide)

* Aspect ratio and WWR not available in CBECS95

WWR Assignment – Office (> 6000 sf) Example

Weights from CBECS92

(First Dice Roll)

WWR BIN	Weight
0-10%	0.39
11-25%	0.30
26-50%	0.19
51-75%	0.08
75-100%	0.04
	1.00

Weight Within Bin

(Second Dice Roll)

WWR	Weight
0%	0.00
2%	0.10
4%	0.15
6%	0.20
8%	0.25
10%	0.30
	1.00

Example of WWR assignment for a large (>6000 sq.ft.) office building based on a “double roll of the dice” model (2 random assignments). The first dice roll bins are weighted by the frequency of occurrence in CBECS92 for a building of that size and type, then within those bins the probability of a given WWR is determined by a second roll of the dice.

Key Mechanical System Parameters - EER

EER Level	Source
8.5	Energy Policy and Conservation Act (EPCA) minimum for 135-240 kBtu/h
8.9	EPCA minimum for 65-135 kBtu/h
9.5	ASHRAE 90.1-1999 minimum for 135-240 kBtu/h
10.0	Selected 0.5 EER increment
10.1	ASHRAE 90.1-1999 minimum for 65-135 kBtu/h
10.5	Selected 0.5 EER increment
11.0	Selected 0.5 EER increment
11.5	Highest reported EER for 135-240 kBtu/h *
11.8	Highest reported EER for 65-135 kBtu/h*
12.0	Selected 0.5 EER increment

* Based on January 2002 ARI certification directory. Current (Sept 2002) online ARI PrimeNet directory has 13.5 EER for the 65-135 kBtu/h and 13.1 kBtu/h for 135-240 kBtu/h categories. This manufacturer indicates product availability in October 2002

Key Mechanical System Parameters

- Sizing
  - Based on ASHRAE 1% Design Day condition
- Over-sizing Factor
  - Randomly chosen: 0% - 25%
- Economizer
  - Enthalpy economizer control assumed when CBECS indicated presence of economizer
- Set Points
  - Heating set point 70°F
  - Cooling set point 75°F
  - 10°F Temperature setback or setup when setback indicated by CBECS

Key Mechanical System Parameters (Continued)

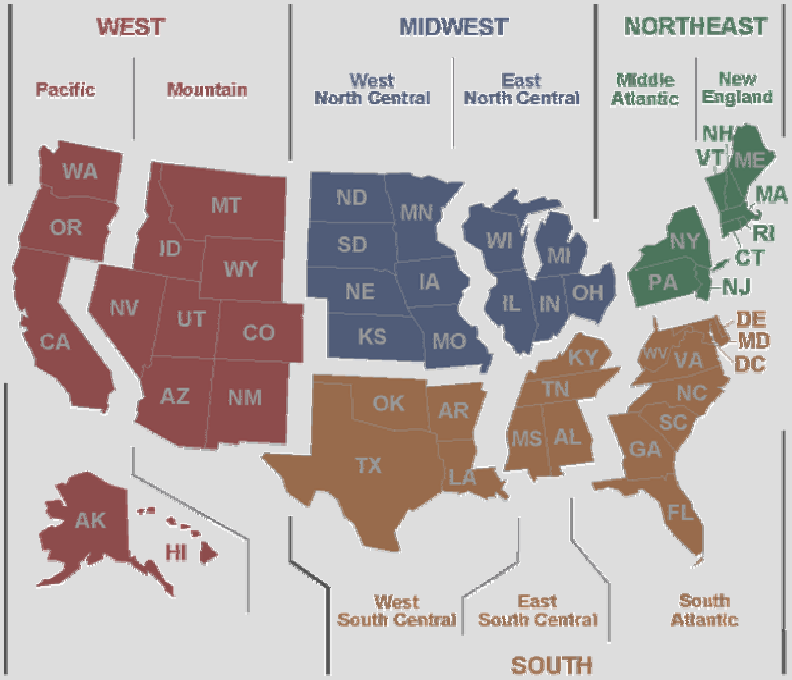
- Total Fan Pressure =Internal Fan Static Pressure + External Fan Static Pressure
- Internal Fan Static Pressure
  - Ratio of fan power to total system power (at rated conditions) held constant across all EER levels
- External Fan Static Pressure
  - Assembly, Education, Office: 1.25 (in. w.g.)
  - Food Services, Retail, Warehouse: 0.75 (in. w.g.)

Key Mechanical System Parameters - Ventilation

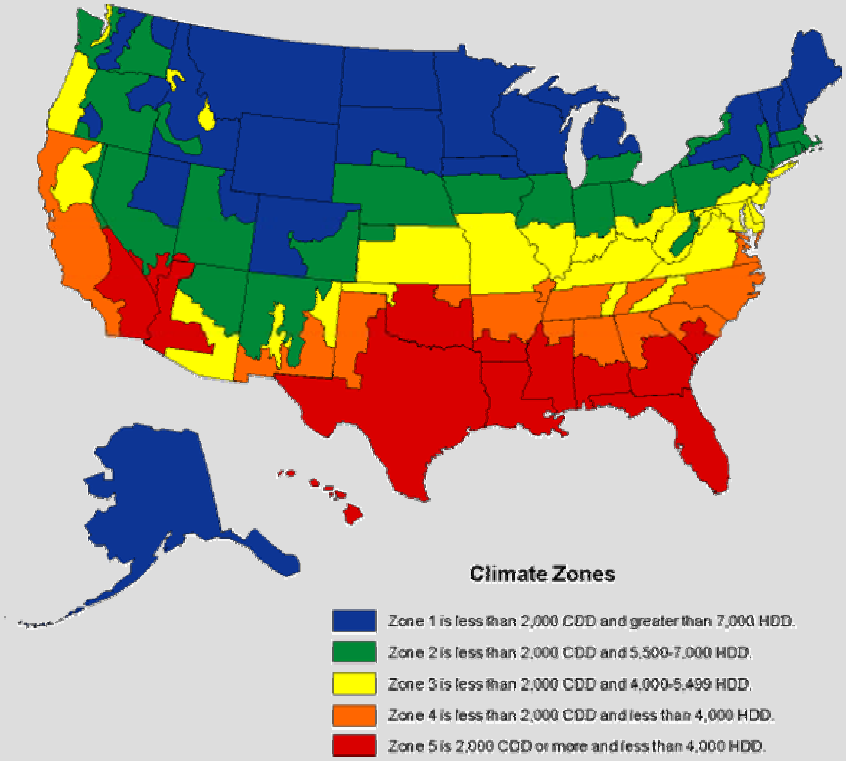
- CFM/floor area used in building simulations
  - Assembly – 0.890 cfm/sf
  - Education – 0.450 cfm/sf
  - Food Service – 0.600 cfm/sf
  - Office – 0.140 cfm/sf
  - Retail – 0.281 cfm/sf
  - Warehouse – 0.050 cfm/sf
- Based on ASHRAE Standard 62-2001 CFM/floor area requirements for Retail and Warehouse, and peak CFM/person for other building types

Climate Station Assignment

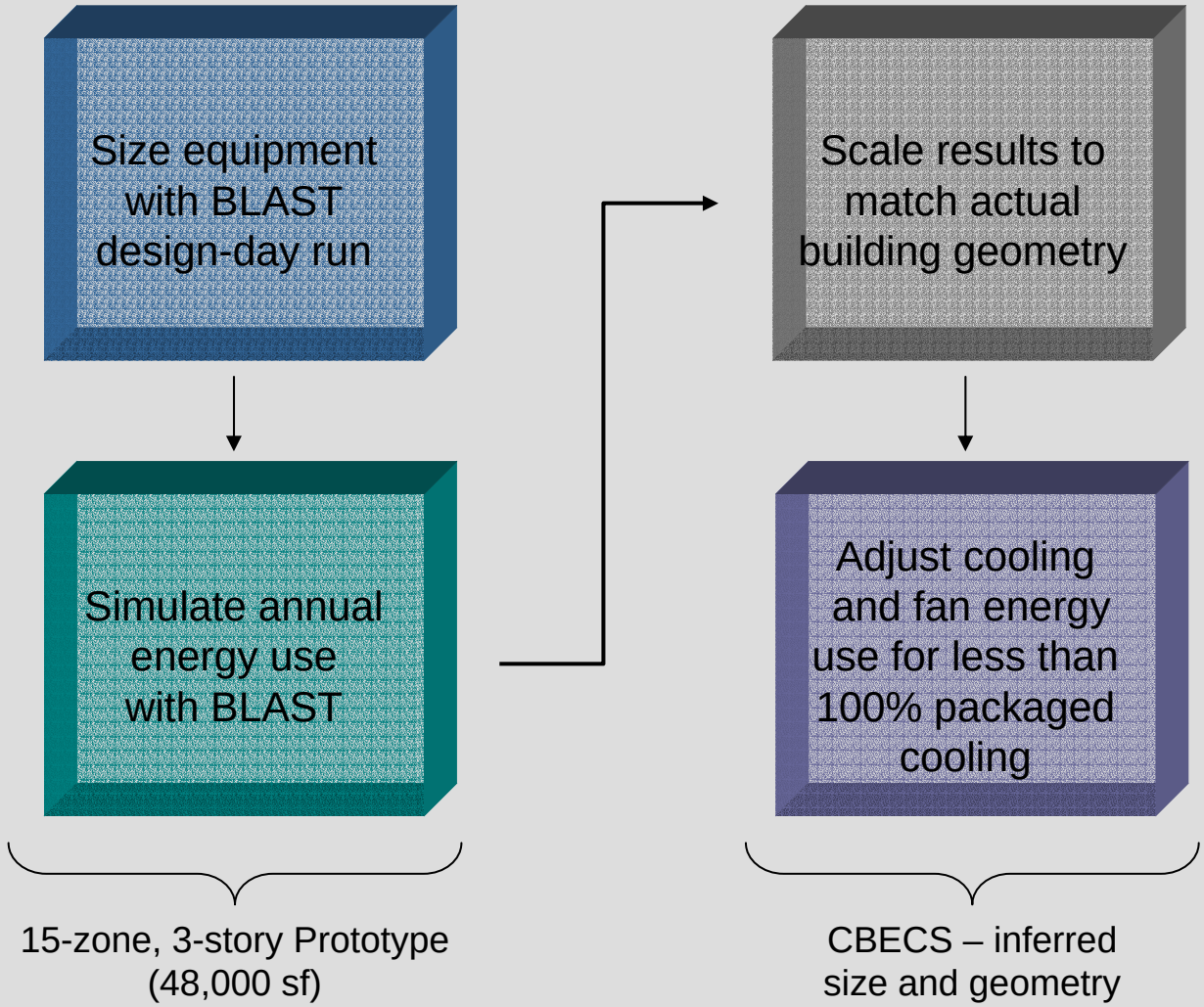
- Nine census divisions overlaid with 5 Climate Zones results in 26 GeoClimate Zones



- Within each GeoClimate zone buildings were assigned to a TMY2 station using population weights



Simulation Methodology

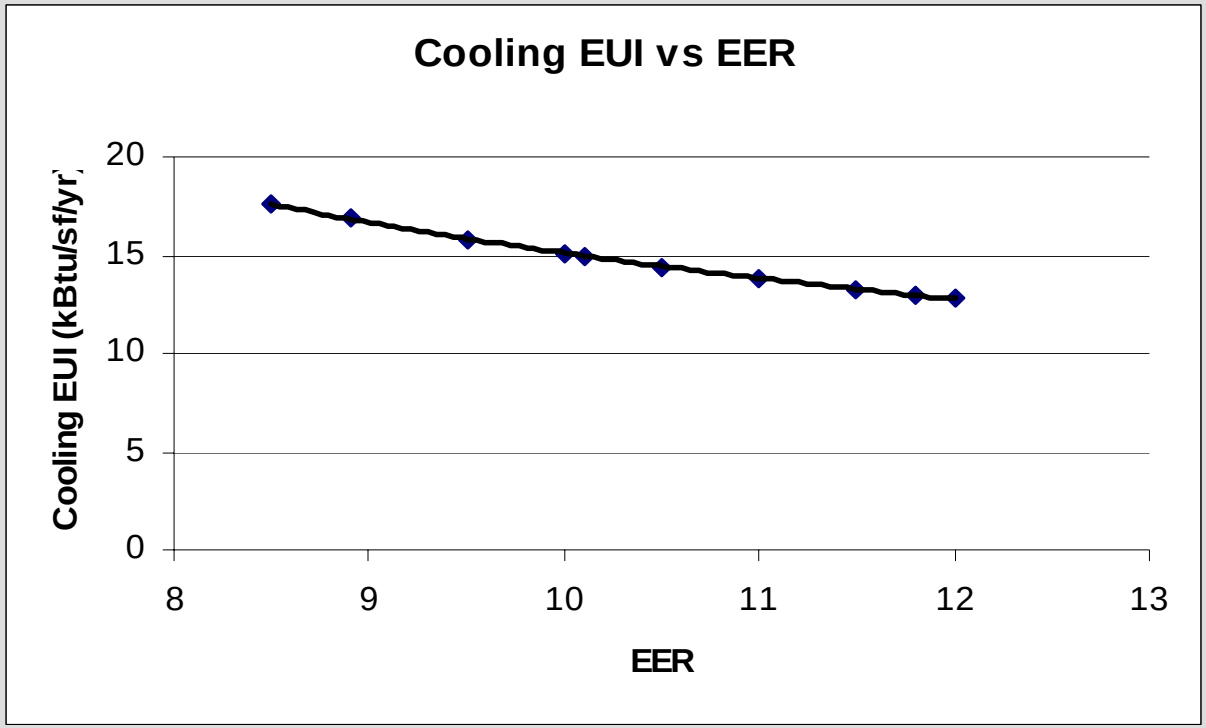


BLAST Model Output

- 1033 Buildings
- 10 EER Levels
- 8760 Hours
- Energy End Uses
  - Cooling – packaged equipment
  - Heating
  - Lights
  - Plug and miscellaneous loads
  - Fan – packaged equipment

Results – Current Analysis

Weighted Cooling Energy Use Intensity (EUI)
Across all 1033 Buildings (Includes Fan Energy)



Comparison with DOE Screening Analysis

	8.9 EER kWh/yr/ton	11.0 EER kWh/yr/ton	Savings kWh/yr/ton
Screening	2027	1677	395
Current	1987	1629	358